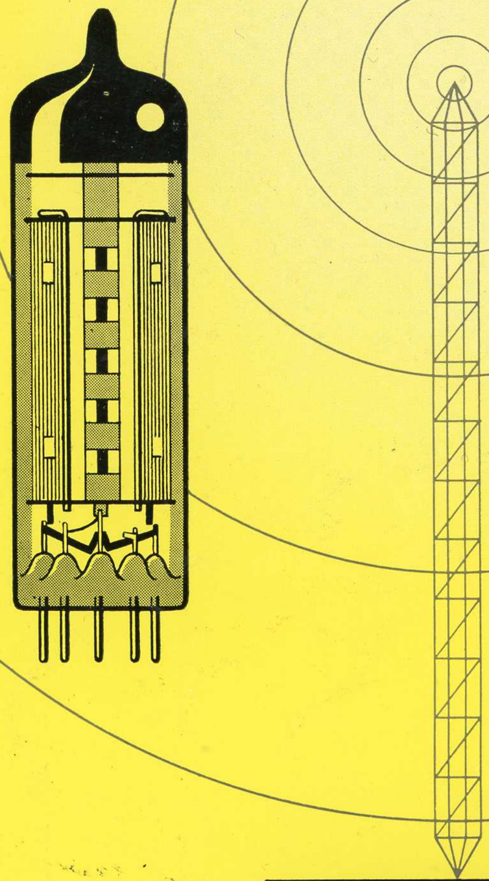
PHILIPS



QQE 03/12

Double Tetrode for Mobile Transmitting Equipment

PHILIPS ELECTRONIC TUBE DIVISION

PREFACE

R.F.amplifiers in mobile transmitting equipment, operating at frequencies higher than 100 Mc/s are preferably designed with push-pull circuits, because these circuits offer the advantages of low parasitic capacitances, low radiation and simple construction. When the two tube systems, required for push-pull operation, are incorporated in a single envelope, the inductances between the cathodes and screen grids can be made low; they can be reduced to an ultimate limit when a common cathode and a common screen grid are used for both tube systems.

This idea has already been successfully applied to the double tetrodes QQE 06/40 and QQE 03/20, and now a small double tetrode, type QQE 03/12, which has been designed along the same lines, is available. The QQE 03/12 gives excellent performance in the frequency range up to 200 Mc/s. Owing to its small dimensions and rigid construction the QQE 03/12 is very suitable for use in mobile equipment and it is an attractive tube in the pre-stages of fixed transmitters.

This Bulletin contains complete data of the QQE 03/12, including operating conditions for use as a push-pull amplifier, frequency tripler, and modulator. The tube sections can also be used in cascade; in such circuits frequency multiplying factors up to 16 can be obtained with only one tube.

On the hand of practical circuits it will be demonstrated that only a small amount of components is required for the construction of compact transmitters with a high frequency stability and a high efficiency.

The information given in this Bulletin does not imply a licence under any patent.

CONTENTS

QQE 03/12 DOUBLE TETRODE

DESCRIPTION

The QQE 03/12 is a double tetrode with indirectly heated cathode, and is intended for use in low-power transmitter stages operating at frequencies up to 200 Mc/s. It can be used in push-pull circuits as an output tube, driver or frequency tripler. Higher frequency multiplication can be obtained by connecting the tube sections in cascade. Moreover, the QQE 03/12 can be used as a modulator output tube, one QQE 03/12 in class C telephony adjustment being modulated with another tube of the same type.

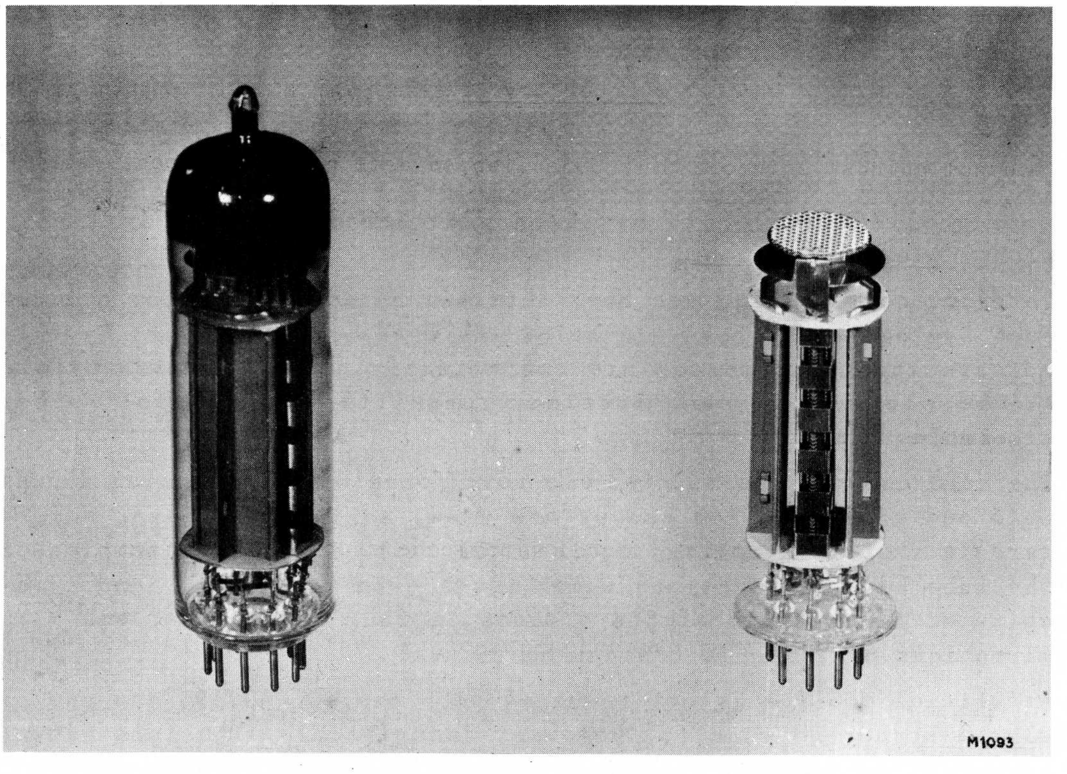


Fig.1. Double tetrode QQE 03/12 (left); the electrode system is shown right.

The cathode of the QQE 03/12 is oxide-coated and provided with a center-tapped heater the sections of which can be used either in parallel or in series. In the former case the heater current is 0.82 A, the voltage being 6.3 V; in the latter case a 0.41 A heater current flows at a voltage of 12.6 V.

When in mobile equipment utmost efficiency with respect to supply power is required, one of the heater sections may be switched off in stand-by position to be switched on simultaneously with the anode voltage when the transmitter is to be operated.

With 300 V supply voltage and both systems operating in push-pull class C telegraphy adjustment, one QQE 03/12 double tetrode can deliver 12 W useful power into the load when used in continuous commercial service (C.C.S.), and 16 W in intermittent commercial or amateur service (I.C.A.S.), in both cases at frequencies up to 200 Mc/s.

Fig.2 shows the cross sectional drawing of the QQE 03/12. The cathode has a rectangular cross section and is coated only at the long sides. Two flat gold-plated grids are placed at each coated side; they are surrounded by the hexagonal screen grid. The control grids and the screen grid are "shadowed", which means that the screen-grid wires are placed behind the control-grid wires in the direction of the electron flow. This measure promotes the formation of a radial beam and ensures the correct space charge conditions between the screen grid and anode. Moreover, shadowed grids are favourable for obtaining a relatively low screen-grid current.

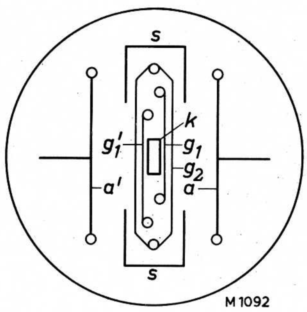


Fig. 2. Cross-sectional drawing of the QQE 03/12.

A screen is placed along the rods of the screen grid and partially extends in the space between the anodes and the screen grid; the extending parts act as beam plates and prevent secondary emission electrons released from the anode from flowing to the screen grid. This screen is connected to the cathode. The anodes are coated and provided with cooling fins; both measures contribute to the relatively high anode dissipation.

Internal neutralising has been obtained by connecting the grid of each system to the base pin below the anode of the other. By this measure the capacitances are sufficiently balanced which offers the possibility of constructing transmitter circuits of rather simple lay-out.

The tube assembly is mounted in a noval envelope. A precision shrunk bulb and a square mica spacer are used, so that the inner structure is rigidly supported against the bulb. Production samples of the tube have to withstand shock tests with the N.R.L. impact machine of five shocks of 500 g each, in four directions, and with vibrations of 2.5 g, 50 c/s during 96 hrs.

Artificial cooling is not required with the QQE 03/12; the use of closed screening cans is, however, inadmissible. The tube socket type 5908/36 is recommended. In mobile equipment a tube retainer can keep the tube in place under conditions of shock and vibration; retainer type 40647 is recommended for the purpose. However, it must be born in mind, that any retainer will absorb some power. With the recommended retainer, this power absorption is 0.3 W at 200 Mc/s.

TECHNICAL DATA

GENERAL DATA

ELECTRICAL

Cathode: indirectly heated, oxide coated

	Heater sections in parallel	Heater sections in series	
Heater voltage 1) 2)	6.3	12.6	V
Heater current	0.82	0.41	A

---

1) Occasional operation at 5.3 or 7.8 volts with parallel connected heaters (10.6 or 15.6 volts with series connection) is permissible.
2) The tube may be used with only half the heater energised during the stand-by period of a transmitter in order to reduce heater current consumption during this time.

Direct interelectrode capacitances

	Each unit	Both units in push-pull	
Output capacitance	2.6	1.4	$\mu\mu F$
Input capacitance	6.2	5.1	$\mu\mu F$
Anode to grid No.1 (internally neutralised)	max. 0.1		$\mu\mu F$

Amplification factor (each unit)

grid No.2 to grid No.1	7.5	

Mutual conductance (each unit)

at anode current = 30 mA	3.3	mA/V

MECHANICAL

Mounting position: Any. If the tube is mounted in a horizontal position it is essential that pins 2 and 7 are placed in a vertical line.

Cooling: Radiation and convection. The use of a closed screening can is not permissible.

Bulb temperature	: max. 225 °C
Temperature of pins	: max. 90 °C
Overall length	: max. 78 mm
Seated length	: max. 72 mm
Diameter	: max. 22 mm
Base	: Noval
Socket	: 5908/36
Tube retainer	: 40647
Net weight	: 16 g
Shipping weight	: 23 g

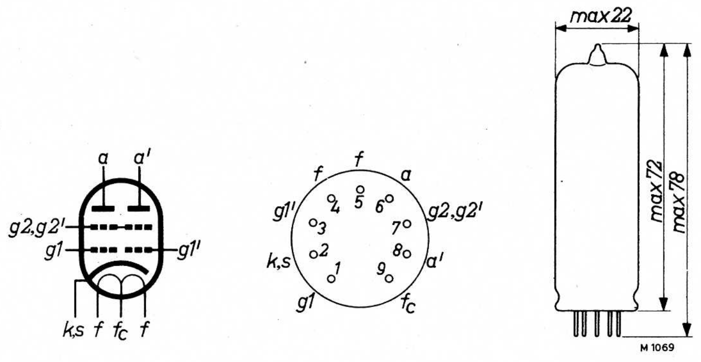


Fig.3. Socket connections and dimensional drawing (dimensions in mm) of QQE 03/12.

pin No.1 = control grid g_1 of unit No.1.
pin No.2 = cathode k and beam plates s.
pin No.3 = control grid g_1' of unit No.2.
pin No.4 = heater f.
pin No.5 = heater f.
pin No.6 = anode a of unit No.1.
pin No.7 = screen grid $g_2 g_2'$.
pin No.8 = anode a' of unit No.2.
pin No.9 = heater mid-tap f_c.

TABLE OF OBTAINABLE POWER

C.C.S. = Continuous Commercial Service.
I.C.A.S. = Intermittent Commercial and Amateur Service.

frequency	H.F. class C					
	telegraphy			anode and screen-grid modulation		
Mc/s	anode voltage (volts)	output power (watts) 1) 2)		anode voltage (volts)	output power (watts) 1) 2)	
		C.C.S.	I.C.A.S.		C.C.S.	I.C.A.S.
200	300	12	16	200	7.1	8.8
	250	9	11.2			
	200	7.4	9			

frequency	H.F. class C frequency tripler		
Mc/s	anode voltage (volts)	output power (watts) 1) 2)	
		C.C.S.	I.C.A.S.
66.6/200	300	3.5	4.8
	250	3	4.2
	200	2.8	3.5

A.F. class AB amplifier or modulator 1)		
anode voltage (volts)	output power (watts)	
	AB 1	AB 2
300	12	17
250	9.3	14
200	7	8.7

1) Two units in push-pull.
2) Useful power output in load.

LIMITING VALUES AND OPERATING CONDITIONS

H.F.CLASS C TELEGRAPHY (up to 200 Mc/s)

LIMITING VALUES *(absolute limits)*

	C.C.S.	I.C.A.S.	
Anode voltage............max.	300	300	V
Anode current............max.	2 x 45	2 x 55	mA
Anode dissipation ....max.	2 x 5	2 x 7	W
Anode input power.........max.	2 x 11.25	2 x 15	W
Screen grid voltage.......max.	200	200	V
Screen grid dissipation...max.	2 x 1	2 x 1	W
Control grid voltage......max.	- 150	- 150	V
Control grid dissipation..max.	2 x 0.2	2 x 0.2	W
Control grid current......max.	2 x 3	2 x 4	mA
Cathode current...........max.	2 x 50	2 x 65	mA
Peak cathode current......max.	2 x 225	2 x 300	mA
Voltage between cathode and heater...max.	100	100	V

OPERATING CONDITIONS (two units in push-pull)

	C.C.S.			
Frequency......................	200	200	200	Mc/s
Anode voltage (=supply voltage)..	300	250	200	V
Screen grid voltage.............	175			V
Control grid bias...............	-40			V
Screen grid dropping resistor....		47	22	kΩ
Common control grid bias resistor		18	15	kΩ
Peak grid-to-grid driving voltage	110	110	115	V
Anode current..................	2 x 37.5	2 x 33.5	2 x 35	mA
Screen grid current.............	2.3	1.8	2.2	mA
Control grid current............	2 x 0.9	2.2	2.7	mA
Driving power..................	2 x 0.05	0.12	0.14	W
Anode input power..............	2 x 11.25	2 x 8.4	2 x 7	W
Anode dissipation...............	2 x 4	2 x 2.9	2 x 2.8	W
Screen grid dissipation..........	0.4	0.3	0.33	W
Output power...................	14.5	11	8.4	W
Efficiency......................	65	65	60	%
Useful output power in load......	12	9	7.4	W

OPERATING CONDITIONS (two units in push-pull)

	I.C.A.S.			
Frequency......................	200	200	200	Mc/s
Anode voltage (=supply voltage)..	300	250	200	V
Screen grid voltage.............	200			V
Control grid bias...............	-45			V
Screen grid dropping resistor....		27	8.2	kΩ
Common control grid bias resistor		18	15	kΩ
Peak grid-to-grid driving voltage	130	120	130	V
Anode current..................	2 x 50	2 x 40	2 x 42	mA
Screen grid current.............	3	2.4	3.1	mA
Control grid current............	2 x 1.5	2.5	3	mA
Driving power..................	2 x 0.1	0.15	0.18	W
Anode input power..............	2 x 15	2 x 10	2 x 8.4	W
Anode dissipation...............	2 x 5.8	2 x 3.5	2 x 3.4	W
Screen grid dissipation..........	0.6	0.45	0.55	W
Output power...................	18.5	13	10	W
Efficiency......................	62	65	60	%
Useful output power in load......	16	11.2	9	W

H.F.CLASS C ANODE AND SCREEN GRID MODULATION (up to 200 Mc/s)

LIMITING VALUES (absolute limits)

	C.C.S.	I.C.A.S.	
Anode voltage............max.	240	240	V
Anode current............max.	2 x 37.5	2 x 46	mA
Anode dissipation........max.	2 x 3.3	2 x 4.6	W
Anode input power........max.	2 x 7.5	2 x 10	W
Screen grid voltage......max.	200	200	V
Screen grid dissipation...max.	2 x 0.65	2 x 0.65	W
Control grid voltage.....max.	- 150	- 150	V
Control grid dissipation..max.	2 x 0.2	2 x 0.2	W
Control grid current.....max.	2 x 3	2 x 4	mA
Cathode current..........max.	2 x 40	2 x 52	mA
Peak cathode current.....max.	2 x 180	2 x 240	mA
Voltage between cathode and heater...max.	100	100	V

OPERATING CONDITIONS (two units in push-pull)

	C.C.S.	I.C.A.S.	
Frequency.....................	200	200	Mc/s
Anode voltage (=supply voltage).....	200	200	V
Screen grid potentiometer R_1=	12	12	kΩ
(see circuit below) R_2=	39	33	kΩ
Screen grid voltage..........	176	173	V
Common control grid bias resistor.......	33	15	kΩ
Peak grid-to-grid driving voltage......	130	130	V
Anode current...............	2 x 33.5	2 x 43	mA
Screen grid current..........	2.6	3.1	mA
Control grid current.........	1.5	3.3	mA
Driving power...............	0.1	0.2	W
Anode input power...........	2 x 6.7	2 x 8.6	W
Anode dissipation...........	2 x 2.65	2 x 3.7	W
Screen grid dissipation......	0.46	0.54	W
Output power................	8.1	9.8	W
Efficiency..................	60	57	%
Useful output power in load.....	7.1	8.8	W
Modulation factor.............	1	1	
Modulation power.............	6.7	8.6	W

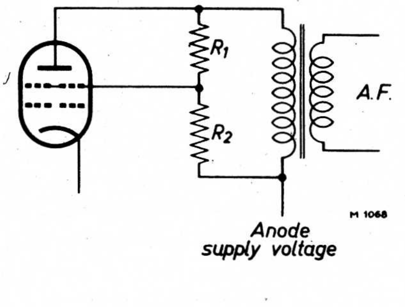


Fig.4. Circuit denoting R_1 and R_2.

H.F.CLASS C FREQUENCY TRIPLER(up to 200 Mc/s)

LIMITING VALUES(absolute limits)

		C.C.S.	I.C.A.S.	
Frequency	max.	200	200	Mc/s
Anode voltage	max.	300	300	V
Anode current	max.	2 x30	2 x 42	mA
Anode dissipation	max.	2 x 5	2 x 7	W
Anode input power	max.	2 x 7.5	2 x 10	W
Screen grid voltage	max.	200	200	V
Screen grid dissipation	max.	2 x 1	2 x 1	W
Control grid voltage	max.	- 150	- 150	V
Control grid dissipation	max.	2 x 0.2	2 x 0.2	W
Control grid current	max.	2 x 2	2 x 3	mA
Cathode current	max.	2 x 35	2 x 45	mA
Peak cathode current	max.	2 x 225	2 x 300	mA
Voltage between cathode and heater	max.	100	100	V

OPERATING CONDITIONS (two units in push-pull)

		C.C.S.		
Input frequency	66.6	66.6	66.6	Mc/s
Output frequency	200	200	200	Mc/s
Anode voltage(=supply voltage)	300	250	200	V
Screen grid voltage	150	160	155	V
Control grid bias	-100			V
Screen grid dropping resistor		47	15	kΩ
Common control grid bias resistor		47	33	kΩ
Peak grid-to-grid driving voltage	230	230	230	V
Anode current	2 x 24	2 x 25	2 x28.5	mA
Screen grid current	2	1.9	3	mA
Control grid current	2 x 1	2	3.2	mA
Driving power	2 x 0.12	0.23	0.35	W
Anode input power	2 x 7.2	2x6.25	2x5.7	W
Anode dissipation	2 x 4	2x3.75	2x3.8	W
Screen grid dissipation	0.3	0.3	0.46	W
Output power	6.5	5	3.8	W
Efficiency	45	40	33.5	%
Useful output power in load	3.5	3	2.8	W

OPERATING CONDITIONS (two units in push-pull)

		I.C.A.S.			
Input frequency	66.6	66.6	66.6	66.6	Mc/s
Output frequency	200	200	200	200	Mc/s
Anode voltage(=supply voltage)	300	300	250	200	V
Screen grid voltage	150	175	175	175	V
Control grid bias	-100	-100			V
Screen grid dropping resistor			18	4.7	kΩ
Common control grid bias resistor			27	22	kΩ
Peak grid-to-grid driving voltage	240	230	230	230	V
Anode current	2x32.5	2x32.5	2x36	2 x 39	mA
Screen grid current	3.5	2.7	4.1	5.2	mA
Control grid current	2 x 1.9	2 x 1.2	3.8	4.6	mA
Driving power	2x0.23	2x0.14	0.43	0.52	W
Anode input power	2 x 9.7	2 x 9.7	2 x 9	2 x 7.8	W
Anode dissipation	2 x 5.8	2 x 6.1	2 x 5.9	2 x 5.55	W
Screen grid dissipation	0.53	0.47	0.72	0.91	W
Output power	7.8	7.2	6.2	4.5	W
Efficiency	40	37	34.5	29	%
Useful output power in load	4.8	4.2	4.2	3.5	W

A.F. CLASS AB AMPLIFIER OR MODULATOR

(for music or speach only)

LIMITING VALUES (absolute limits)

Anode voltage	max.	300	V
Anode current	max.	2x50	mA
Anode dissipation	max.	2 x 7	W
Anode input power	max.	2x15	W
Screen grid voltage	max.	200	V
Screen grid dissipation	max.	2 x 1	W
Screen grid peak dissipation	max.	2 x 2	W
Control grid voltage	max.	-150	V
Control grid dissipation	max.	2x0.2	W
Control grid current	max.	2x4	mA
Control grid resistor	max.	100	kΩ
Cathode current	max.	2x60	mA
Peak cathode current	max.	2x300	mA
Voltage between cathode and heater	max.	100	V

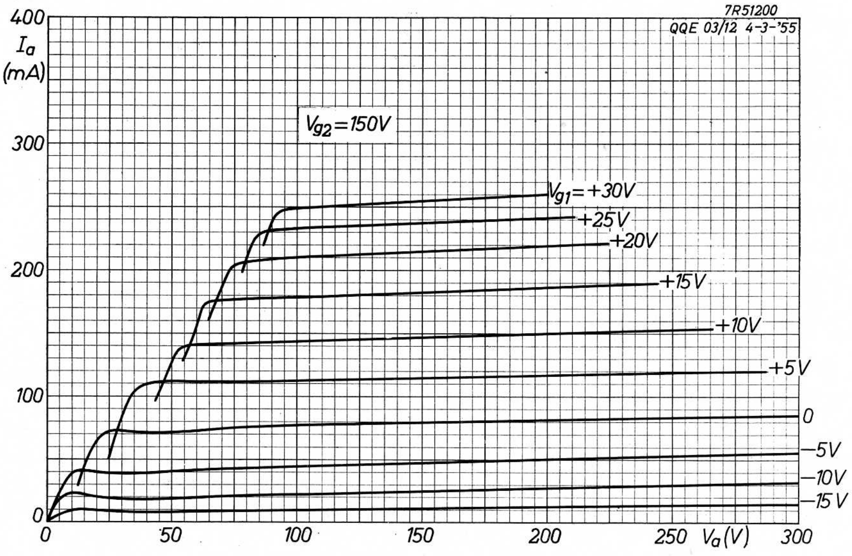
OPERATING CONDITIONS

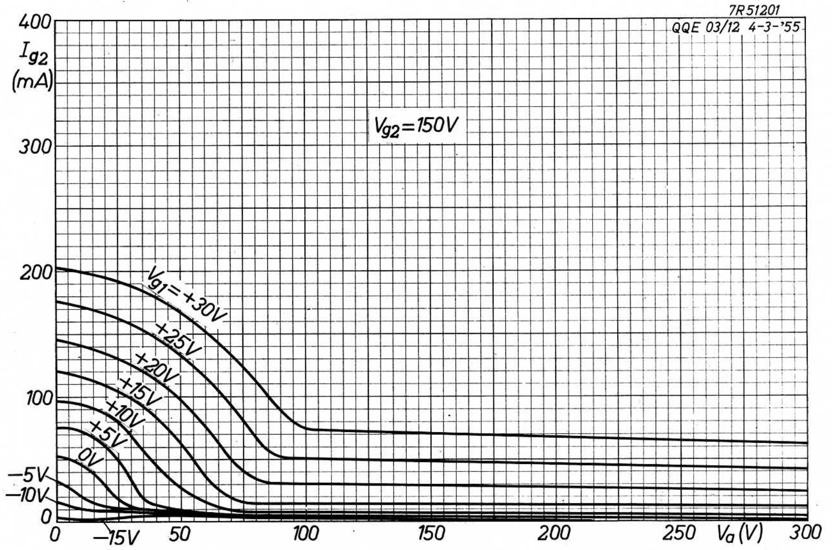
A.F.class AB 1

Anode voltage	300		250		200		V
Screen grid voltage	200		200		200		V
Control grid voltage	-21.5		-21.5		-21.5		V
Load resistance between anodes	10		8		6.5		kΩ
Driving voltage peak to peak	0	43.5	0	44.5	0	43.5	V
Anode current	2x15	2x36	2x15	2x34.5	2x15	2x33	mA
Screen grid current	2x0.6	2x6.3	2x0.7	2x6.2	2x1.2	2x7	mA
Anode input power	2x4.5	2x10.8	2x3.75	2x8.65	2 x 3	2x6.6	W
Anode dissipation	2x4.5	2x4.8	2x3.75	2 x 4	2 x 3	2x3.1	W
Screen grid dissipation	2x0.12	2x1.3	2x0.14	2x1.3	2x0.24	2x1.4	W
Output power		12		9.3		7	W
Total distortion		2.5		2.7		3.2	%
Efficiency		56		54		53	%

A.F. class AB 2

Anode voltage	300		250		200		V
Screen grid voltage	200		200		200		V
Control grid voltage	-21.5		-21.5		-21.5		V
Load resistance between anodes	6.5		5		5		kΩ
Driving voltage peak to peak	0	64	0	67	0	54	V
Anode current	2x15	2x50	2x15	2x50	2x15	2x41.1	mA
Screen grid current	2x0.6	2x5.7	2x0.7	2x6.5	2x1.2	2x9.5	mA
Control grid current	0	2x0.56	0	2x0.62	0	2x0.22	mA
Driving power	0	2x0.02	0	2x0.02	0	2x0.01	W
Anode input power	2x4.5	2x15	2x3.75	2x12.5	2x3	2x8.22	W
Anode dissipation	2x4.5	2x6.25	2x3.75	2x5.5	2x3	2x3.87	W
Screen grid dissipation	2x0.12	2x1.2	2x0.14	2x1.3	2x0.24	2x1.9	W
Output power		17.5		14		8.7	W
Total distortion		5		5.5		6	%
Efficiency		58		56		53	%





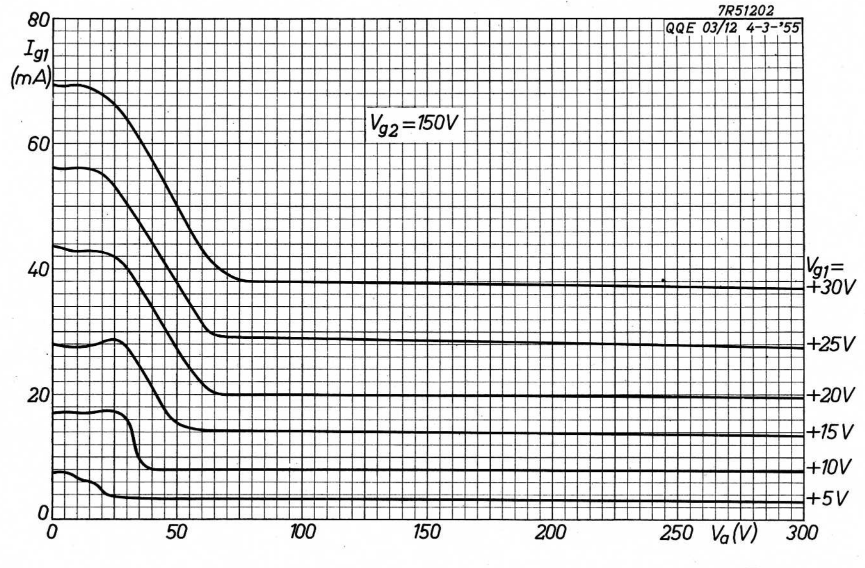
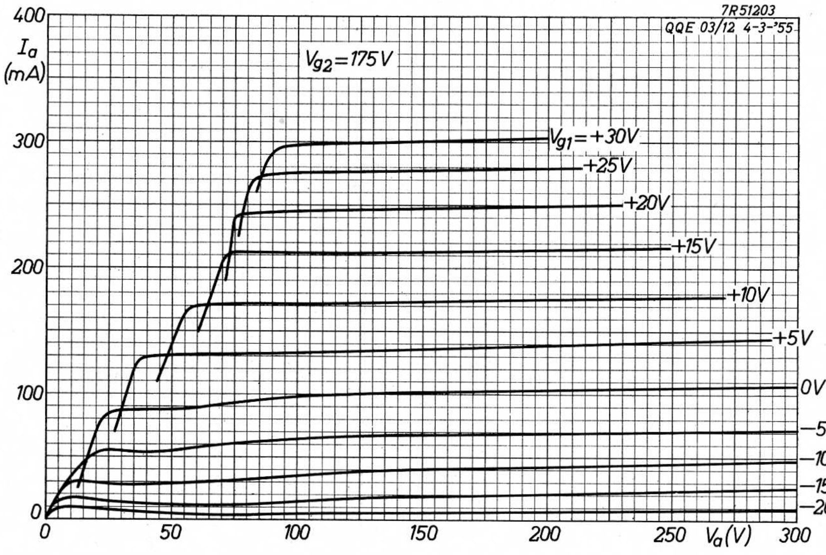
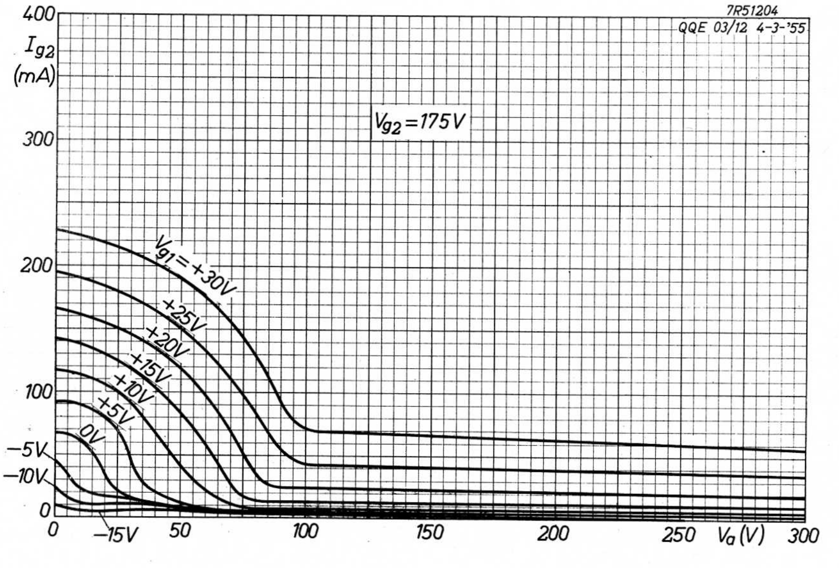


Fig.5, 6 and 7. Anode current I_a, screen grid current I_{g2} and control grid current I_{g1} as functions of the anode voltage V_a with the control grid voltage V_{g1} as parameter at a screen-grid voltage V_{g2} = 150 V (all current values per unit).





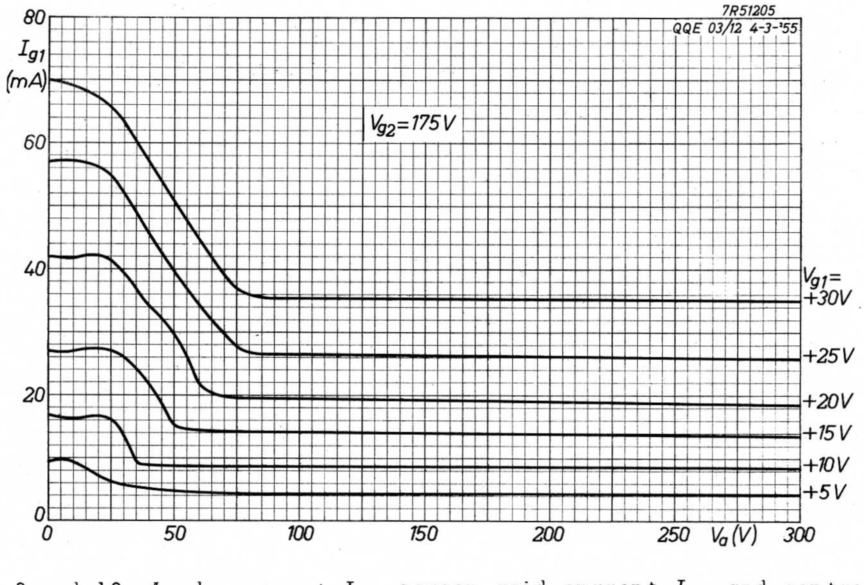
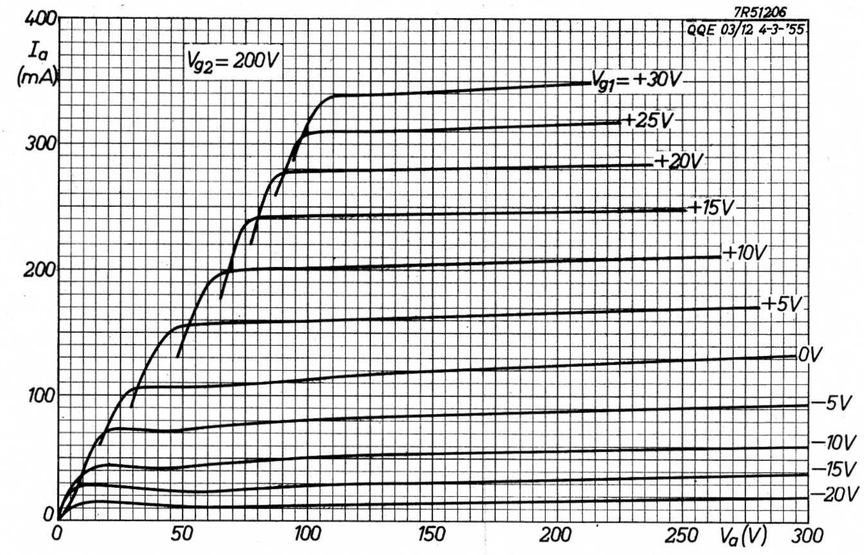
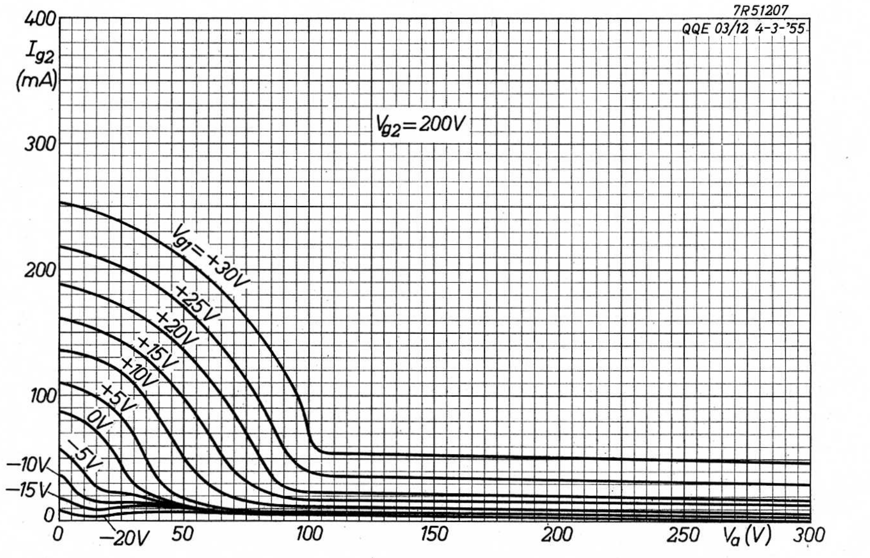


Fig. 8, 9 and 10. Anode current I_a, screen grid current I_{g2} and control grid current I_{g1} as functions of the anode voltage V_a with the control grid voltage V_{g1} as parameter at a screen-grid voltage V_{g2} = 175 V (all current values per unit).





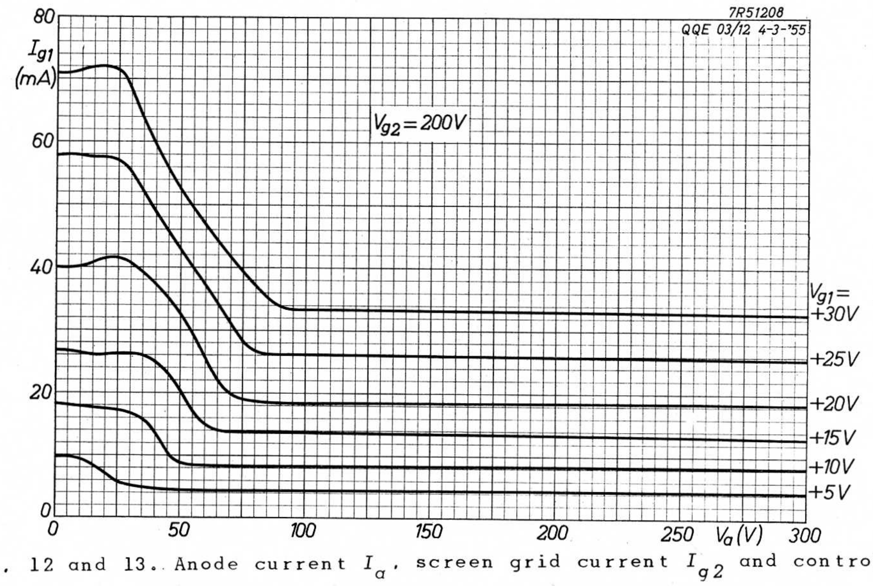
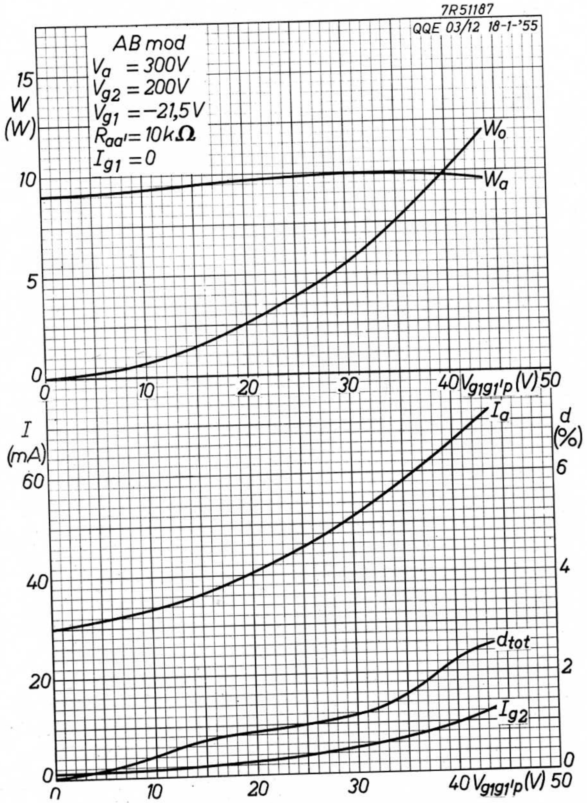
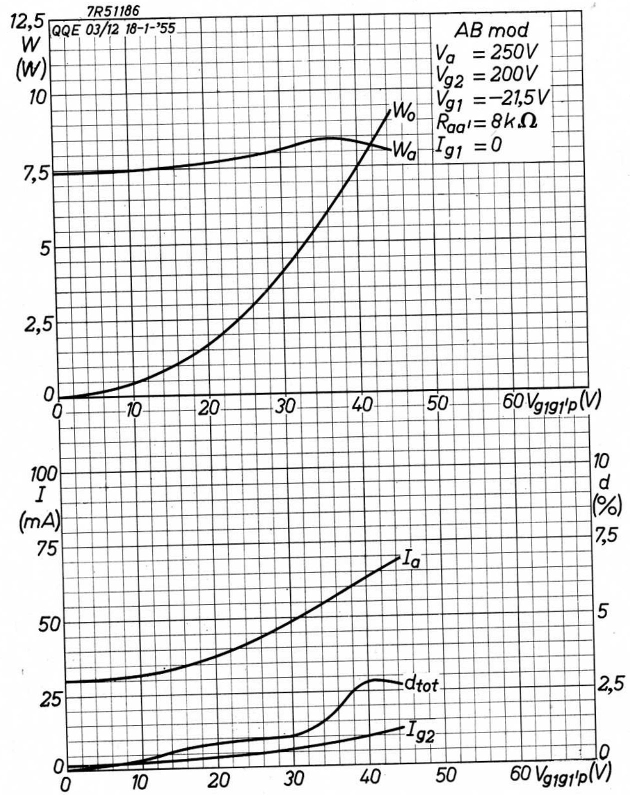


Fig.11, 12 and 13. Anode current I_a, screen grid current I_{g2} and control grid current I_{g1} as functions of the anode voltage V_a with the control grid voltage V_{g1} as parameter at a screen-grid voltage V_{g2} = 200 V (all current values per unit).





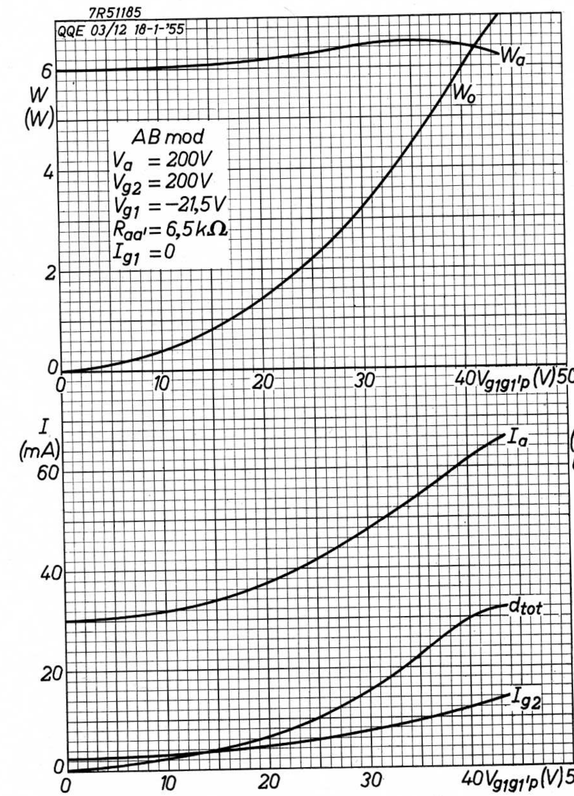


Fig.14, 15 and 16. Output power W_o, anode dissipation W_a, anode current I_a, screen grid current I_{g2} and total distortion d_{tot} as functions of the peak-to-peak driving voltage $V_{g1g1'p}$ for two units in push-pull AB1 operation at different anode voltages V_a and different load resistances R_{aa}' between anodes. Screen grid voltage V_{g2} = 200 V and control grid bias V_{g1} = -21.5 V.

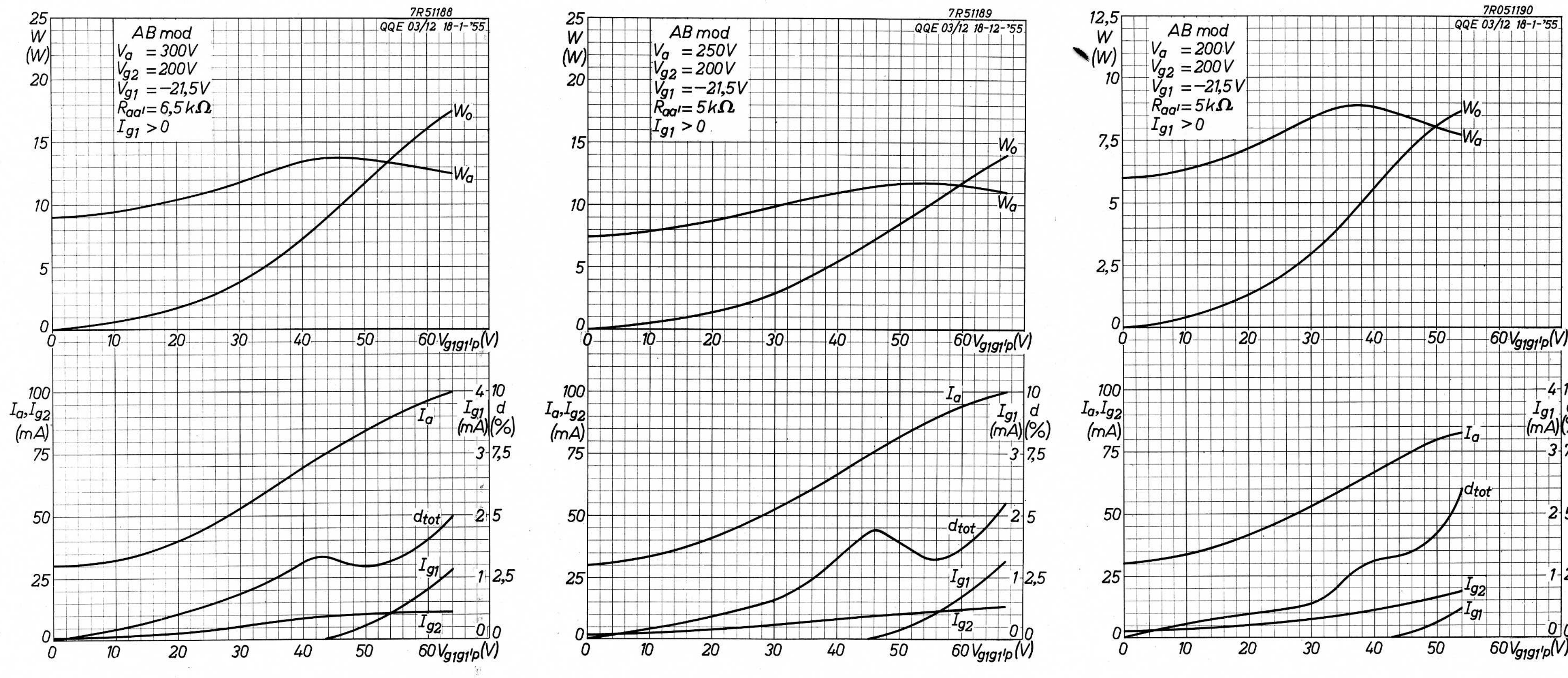


Fig.17, 18 and 19. Output power W_o, anode dissipation W_a, anode current I_a, screen grid current I_{g2}, control grid current I_{g1}, and total distortion d_{tot} as functions of the peak-to peak driving voltage $V_{g1g1'p}$ for two units in push-pull AB2 operation at different anode voltages V_a and different load resistances $R_{aa'}$ between anodes. Screen grid voltage V_{g2} = 200 V and control grid bias V_{g1} = -21.5 V.

OPERATIONAL NOTES

1. HEATER VOLTAGE

It has already been stated that the QQE 03/12 can be operated at nominal heater voltages of 6.3 or 12.6 V, either a.c. or d.c.With a.c. supply in fixed stations this requires no further comment. Mobile equipment is, however, often fed from storage batteries, and it may then occur that the tube is operated at a lower heater voltage (almost discharged battery),or at a higher voltage (battery being charged during operation).

To cope with conditions of underrunning or overvoltage, as will be met in mobile equipment, the heater of the QQE 03/12 has been so designed that the tube can withstand occasional operation within the limits of 5.3 V or 7.8 V with parallel connected heaters, respectively 10.6 V, or 15.6 V with series connected heaters, without the tube life being affected.

In order to reduce heater current during stand-by, it is possible to keep only one heater section switched on, the other being switched on simultaneously with the anode voltage. Full output is then available immediately.

2. ASYMMETRY

As with all double tubes a slight asymmetry between the two sections cannot always be prevented. A number of tests have been carried out on the experimental transmitter described in the last chapter of this Bulletin to investigate the influence of several circuits on the asymmetry, especially with respect to the efficiency.

There are external and internal causes for asymmetry. The former can be prevented by careful and symmetric circuit lay-out. Causes of internal asymmetry are: slight differences in tube capacitances, in internal inductances, in the transit times and in the characteristics.

As a rule class C adjustment is not very critical to asymmetry in characteristics, in contrast to class B operation. In the latter case individual adjustment of the grid bias is recommended if distortion has to be kept low. In the transmitter circuit mentioned above,various methods of connecting the supply sources to the circuit,and the use of bypass capacitors, series chokes and dropping resistors have been investigated. The results of these tests are described below as a guidance for equipment designers. This implies by no means that they offer the only solution to the problem it also being possible to obtain good results with other circuits.

A. CENTRE TAP ON THE ANODE-COIL

When the anode circuit is perfectly symmetrical, it makes no difference whether the anode supply is connected directly to the tap of the coil or via a choke, the centre tap of the anode coil being capacitively earthed. However, when some asymmetry occurs - which usually will be the case - and the centre tap of the anode coil is bypassed, part of the R.F. power will flow to earth via the bypass capacitor and be lost. Therefore, the anode circuit should be fed via a choke that is not bypassed, see figs 20a and b.

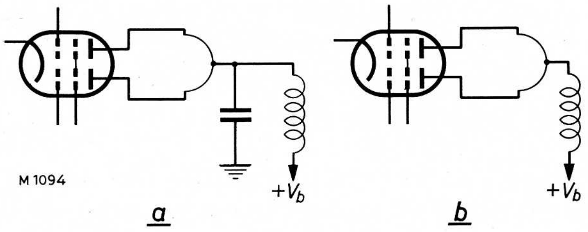


Fig.20. Connecting the H.T.supply to the anode circuit; (*a*) incorrect, (*b*) correct.

B. BYPASSING OF THE SCREEN GRID

When the anode circuit is fed correctly as described under (A), it is immaterial whether the screen grid is bypassed or not.

Some designers are inclined to bypass the screen grid dropping resistors and to feed the screen grid via a choke. This circuit (fig.21*a*), which occasionally gives satisfactory results, may give rise to parasitic oscillations. As a rule the use of an unbypassed dropping resistor gives the best results.

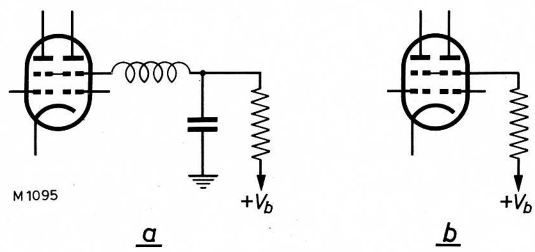


Fig.21. The screen-grid resistor should not be bypassed, and no choke be used in the screen-grid lead; (*a*) incorrect, (*b*) correct.

C. CENTRE TAP ON THE GRID COIL

Experiments reveal that asymmetry is practically annihilated when the centre tap on the grid coil is bypassed to earth. This can be explained as follows.

When the centre tap of the grid coil is earthed, the driving voltages in the coil halves are substantially equal and independent of the input capacitances of each tube section, provided the circuit lay-out is symmetric, and the coupling of the pre-stage is tight. However, when the grid leak is not bypassed (see fig. 22*a*), asymmetry of the input capacitances will influence the symmetry of the grid drive

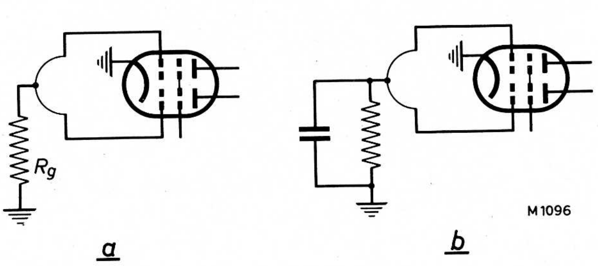


Fig.22. The best symmetry is obtained when a single grid-leak is used, bypassed to earth; (*a*) incorrect, (*b*) correct.

It proved to be immaterial whether two separate grid leaks were used or a single grid leak for both sections. The most simple and economic circuit according to fig.20b, therefore, proved to be the most successful in the tests carried out.

D. CATHODE CONNECTIONS

Coils in the cathode circuit, bypassed or not, affect the stability because they may give rise to parasitic oscillations. The cathode is preferably connected directly to earth.

E. HEATER CONNECTIONS

One heater connection can be directly earthed. If, at 200 Mc/s, the other connection is not bypassed, the driver power must be increased with 60% to obtain the normal anode current, and even then the output is decreased by 33%. This leads to the conclusion that one heater connection should be connected directly to chassis, whereas the other should be earthed capacitively. Much depends, however, on the circuit lay-out. In some cases bypassed chokes included in both heater leads are to be preferred.

CONCLUSION

In the tests carried out the best performance was obtained with the circuit given in fig.23, in which:

a) The centre tap of the anode coil is connected to the H.T. supply via an R.F. choke;
b) the screen grid is fed via an unbypassed dropping resistor;
c) the centre tap of the grid circuit is capacitively earthed;
d) a single grid resistor is used for biasing both control grids;
e) the cathode is connected directly to the chassis;
f) one heater pin is connected directly to the chassis and the other via a capacitor.

Finally, it should be noted that it is important to construct the amplifier stage as symmetrically as possible.

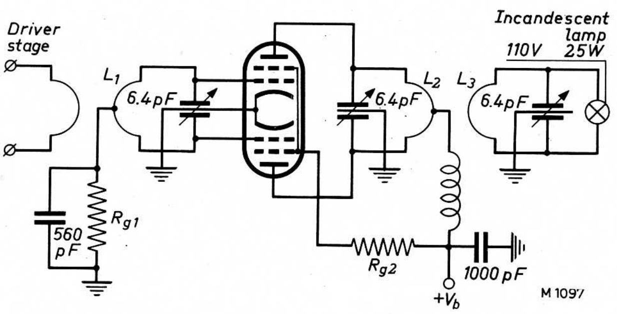


Fig.23. Push-pull output stage with QQE 03/12.

The measurements were carried out with the circuit of fig.23; the output was measured with a calibrated combination of a 110 V, 25 W incandescent lamp and a photocell.

3. TWO-STAGE FREQUENCY MULTIPLIER

Apart from the operation as amplifier and tripler, the QQE 03/12 can be used as a two-stage frequency multiplier by connecting the two systems in cascade. In such circuits (see figs 24a, b, and c) the multiplication factor of each section can be chosen between 1 and 4, so that with both systems used, multiplication factors of 2, 3, 4, 6, 8, 9, 12, or 16 can be obtained.

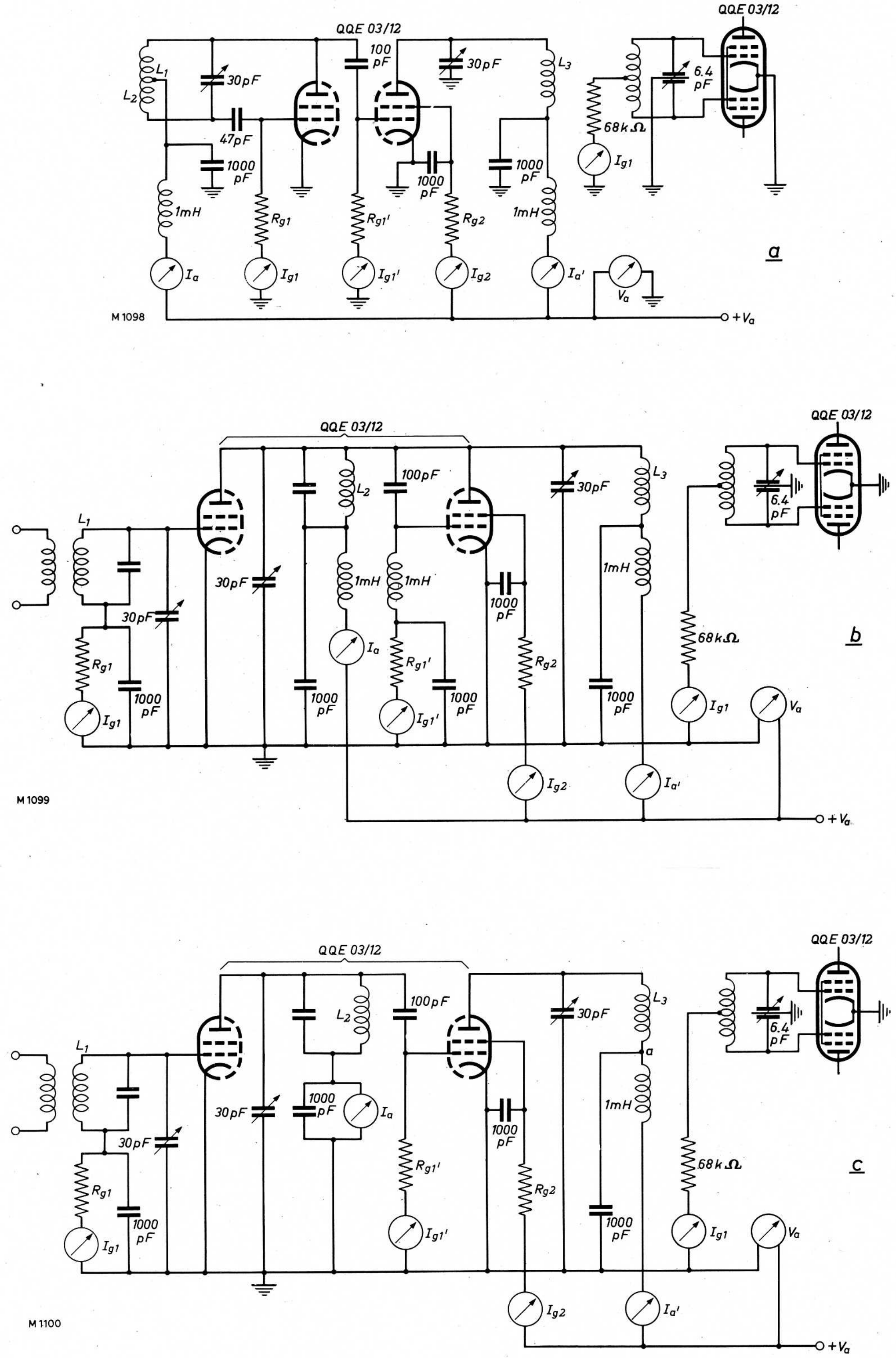


Fig. 24. Circuits of two-stage multipliers with one QQE 03/12.

multiplying factor			frequency (Mc/s)	R_{g1} (kΩ)		R_{g2} (kΩ)	I_{g2} (mA)	I_a (mA)		I_{g1} (mA)		circuit	coil number		
section I	section II	total		section I	section II			section I	section II	section I	section II	fig. no.	L_1	L_2	L_3
1 oscillator	2	2	$33\frac{1}{3}$ $66\frac{2}{3}$	82	82	120	1.1	10	9	0.5	0.9	24a	8 turns 1.8mm tap 3 turns from grid d = 12mm l = 19mm C_{par} = 39 pF		8 turns 1.8mm d = 12mm l = 19mm
1 oscillator	3	3	$22\frac{2}{9}$ $66\frac{2}{3}$	82	82	120	1.1	9	10.5	0.33	1	24a	10 turns 1.8mm tap 3 turns from grid d = 12mm l = 22mm C_{par} = 82 pF		8 turns 1.8mm d = 12mm l = 19mm
1 oscillator	4	4	$16\frac{2}{3}$ $66\frac{2}{3}$	82	82	68	1.7	11.5	12	0.45	1.1	24a	10 turns 0.45 mm tap 3 turns from grid d = 12mm l = 5mm C_{par} = 47 pF		8 turns 1.8mm d = 12mm l = 19mm
3	2	6	$11\frac{1}{9}$ $66\frac{2}{3}$	82	82	150	0.8	13	9.5	0.75	0.7	24b	15 turns 0.45mm d = 12mm l = 8mm C_{par} = 68 pF	8 turns 1.8mm d = 12mm; l = 19mm C_{par} = 27 pF	8 turns 1.8mm d = 12mm l = 19mm
4	2	8	$8\frac{1}{3}$ $66\frac{2}{3}$	82	82	220	0.6	11	8	0.85	0.5	24b	25 turns 0.45mm d = 12mm l = 13mm C_{par} = 56 pF	8 turns 1.8mm d = 12mm; l = 19mm C_{par} = 27 pF	8 turns 1.8mm d = 12mm l = 19mm
3	3	9	$7\frac{11}{27}$ $66\frac{2}{3}$	82	82	150	0.8	12	10.5	0.6	0.85	24b	25 turns 0.45mm d = 12mm l = 13mm C_{par} = 68 pF	8 turns 1.8mm d = 12mm; l = 19mm C_{par} = 100 pF	8 turns 1.8mm d = 12mm l = 19mm
4	3	12	$5\frac{5}{9}$ $66\frac{2}{3}$	82	82	120	0.9	14.5	11	1.1	0.7	24b	42 turns 0.45mm d = 12mm l = 8mm C_{par} = 33 pF	8 turns 1.8mm d = 12mm; l = 19mm C_{par} = 120 pF	8 turns 1.8mm d = 12mm l = 19mm
4	4	16	$4\frac{1}{6}$ $66\frac{2}{3}$	82	82	27	2.4	22	21.5	1.35	1.25	24c	50 turns 0.45mm d = 12mm l = 8mm C_{par} = 33 pF	10 turns 0.45mm d = 12mm; l = 5mm C_{par} = 47 pF	8 turns 1.8mm d = 12mm l = 19mm

The operating conditions for the multiplier stages according to the circuits of fig.23 are given in the table on p.22. The output of all multipliers described is sufficient to drive a push-pull tripler with another QQE 03/12.

Operating conditions in which both systems operate as frequency doublers are not given, because it is more efficient to use one tube section as a quadrupler and the other as an oscillator.

The total parallel capacitance across the grid coil is quoted in the table. This capacitance (C_{par}) consists of the stray capacitances of the coil, the parasitic capacitances of the circuit, and the tuning capacitor.

SMALL EXPERIMENTAL 200 Mc/s TRANSMITTER WITH THREE TUBES QQE 03/12

In this section a small transmitter, operating at about 200 Mc/s, is described. This transmitter has not been made to demonstrate which results can be obtained under the most favourable conditions, but to investigate what the performance will be even when lower limit tubes are used.

The transmitter has been made for use with narrow-band F.M.; two different modulator stages are described. A.M. modulation can be obtained by connecting a modulator via a transformer to the anode circuit of the output stage.

The crystal-controlled master oscillator operates at 4182 kc/s, and since the frequency multiplication in three stages with two tubes QQE 03/12 is 48, the frequency of the output signal is 200.736 Mc/s. The power output, measured in an artificial load, is 7 W.

CIRCUIT DESCRIPTION

Fig.25 shows the circuit diagram of the transmitter. One section of an E 80 CC double triode is used as crystal-controlled master oscillator, operating at 4182 kc/s. The anode of this oscillator is capacitively coupled to a multiplier (multiplication factor 16), equipped with one QQE 03/12 (I), the two systems of which are connected in cascade according to the data and circuit c given in the previous section.

The anode circuit of the second section of the QQE 03/12 (I) is inductively coupled to the symmetrical tripler equipped with the QQE 03/12 (II) which in turn, operates as a driver for the output stage equipped with the QQE 03/12 (III) connected as a push-pull R.F. amplifier.

MODULATOR

Since a crystal-controlled oscillator cannot be frequency modulated, phase modulation is applied which is transformed into frequency modulation by a simple artifice.

Phase modulation is obtained by providing the tuned anode circuit of the oscillator tube with a variable inductance. This is achieved by winding part of the coil on a Ferroxcube rod which is placed on a U-shaped, laminated iron core carrying the A.F. coils on its legs (see fig.26). The anode current of the modulator tube (first section of the E 80 CC) flows through the A.F. coils, so that the inductance of the coil on the Ferroxcube rod varies with the modulation, and phase modulation of the oscillator output voltage is obtained.

Phase modulation can easily be transformed into frequency modulation by rendering the amplitude of the modulation signal inversely proportional to the frequency. In the present circuit this is achieved by connecting the filter R_2C_1 in series with the grid of the modulator tube.

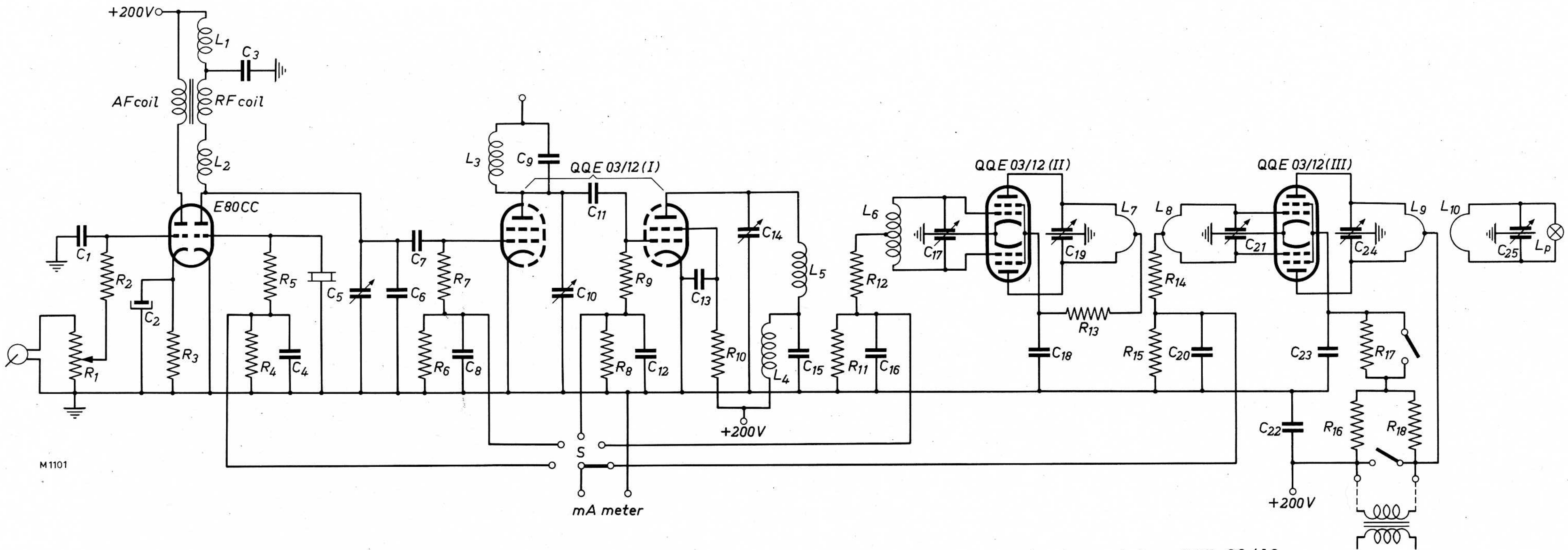


Fig.25. Circuit diagram of the experimental 200 Mc/s transmitter with three tubes QQE 03/12.

LIST OF PARTS

R_1 = 1 MΩ	R_{10} = 27 kΩ	C_1 = 180 pF	C_{10} = 25 pF	C_{19} = 6.4 pF
R_2 = 100 kΩ	R_{11} = 1 kΩ	C_2 = 25 μF *)	C_{11} = 150 pF	C_{20} = 1000 pF
R_3 = 470 Ω	R_{12} = 68 kΩ	C_3 = 1000 pF	C_{12} = 1000 pF	C_{21} = 6.4 pF
R_4 = 1 kΩ	R_{13} = 68 kΩ	C_4 = 1000 pF	C_{13} = 1000 pF	C_{22} = 1000 pF
R_5 = 22 kΩ	R_{14} = 33 kΩ	C_5 = 25 pF	C_{14} = 25 pF	C_{23} = 1000 pF
R_6 = 1 kΩ	R_{15} = 1 kΩ	C_6 = 27 pF	C_{15} = 1000 pF	C_{24} = 6.4 pF
R_7 = 82 kΩ	R_{16} = 39 kΩ	C_7 = 150 pF	C_{16} = 1000 pF	C_{25} = 6.4 pF
R_8 = 1 kΩ	R_{17} = 120 kΩ	C_8 = 1000 pF	C_{17} = 6.4 pF	
R_9 = 82 kΩ	R_{18} = 12 k°	C_9 = 47 pF	C_{18} = 1000 pF	

*) 25 V

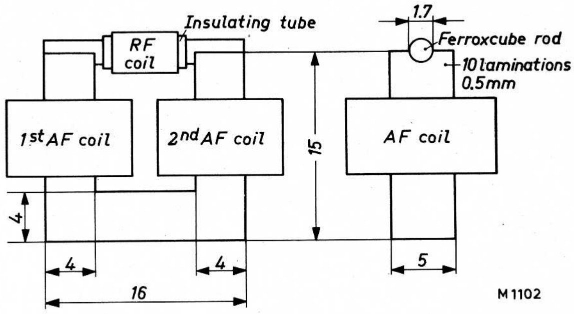


Fig. 26. Diagram and dimensions in mm of the modulation transformer.

The operating conditions of the E 80 CC are tabulated below.

E 80 CC	V_b	I_a	R_g	I_g	V_g
Oscillator	200 V	11.5 mA	22 kΩ	1.95 mA	-
Modulator	200 V	7 mA	-	-	-3.3 V

An alternative modulation circuit is given in fig. 28. In this circuit one section of the E 80 CC is connected as a variable reactance tube and shunted across the anode circuit of the oscillator section. An E 80 F pentode is used as pre-amplifier for the A.F. signal. The values of the resistors and capacitors at the input circuit of the first section of the E 80 CC are so chosen that the required frequency response is obtained for the transformation of phase modulation into frequency modulation. The resistors and capacitors in the feedback circuit introduce the required phase shift so that the reactance tube operates as a variable capacitor shunting the tuned anode circuit of the second section.

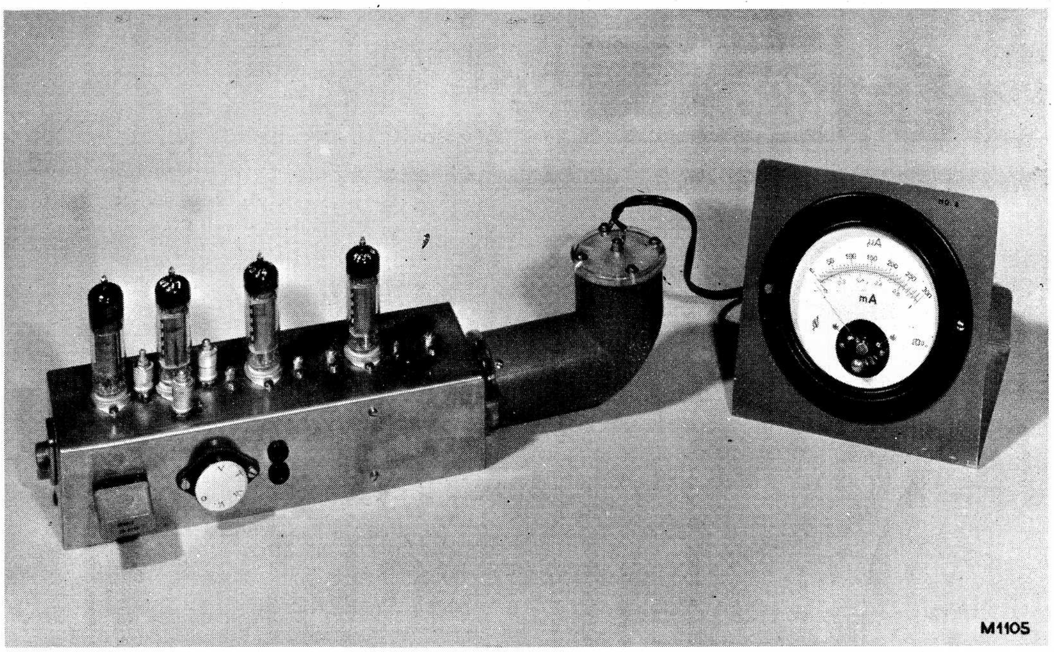


Fig. 27. 200 Mc/s transmitter with artificial load and phototube output meter.

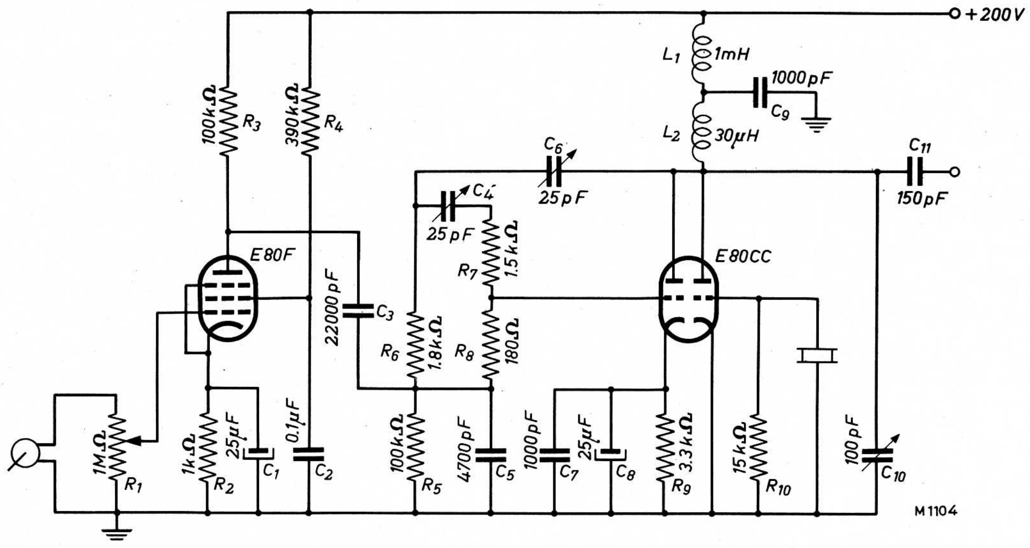


Fig.28. Modified modulator stage of the 200 Mc/s transmitter.

The operating conditions of the oscillator and modulator stages are tabulated below.

Tube	V_b (V)	I_a (mA)	R_{g2} (kΩ)	I_{g2} (mA)	V_k (V)	I_g (mA)
E 80 F	200	1.5	390	0.3	1.8	-
E 80 CC first section	200	2.4	-	-	7.9	-
E 80 CC second section	200	12.6	-	-	-	2.15

With either modulator stage a frequency sweep of 2 x 15 kc/s can be obtained at the output of the transmitter.

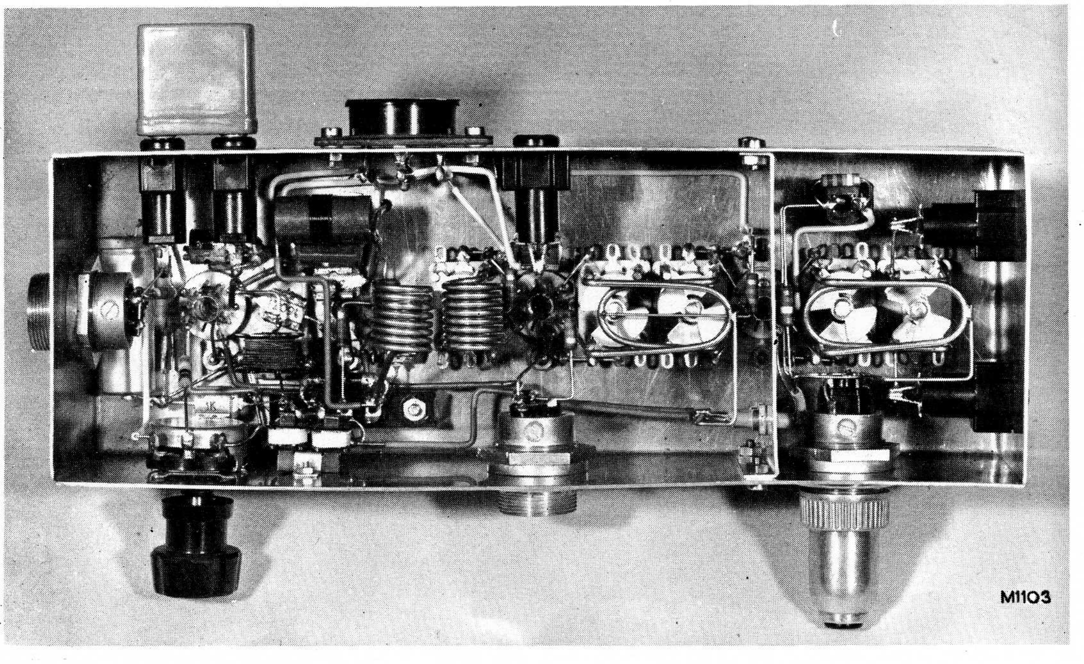


Fig.29. Chassis of the 200 Mc/s transmitter seen from below.

AMPLITUDE MODULATION

Although transmitters of this type are as a rule used with narrow-band frequency modulation. which is the most economical system, A.M. is preferred in some countries.

Amplitude modulation can be applied to the output stage by using combined anode and screen-grid modulation according to the operating conditions given under Technical Data. One QQE 03/12 can be used as a modulator tube, under push-pull class AB_1 or class AB_2 conditions.

THE FREQUENCY MULTIPLIER BY 16

For multiplying the frequency by a factor 16, a QQE 03/12 is used with both sections in cascade in a circuit similar to that of fig.24c. The input circuit, however, is capacitively coupled to the oscillator.

The control grid resistors of both tube sections are 82 kΩ, the screen-grid resistor is 27 kΩ. With these values the operating conditions of the multiplier stage are as tabulated below.

<table>
<tr><th>Tube</th><th>Multi-plying factor</th><th>V_b (V)</th><th>I_a (mA)</th><th>I_{g2} (mA)</th><th>I_{g1} (mA)</th></tr>
<tr><td>QQE 03/12 (I) first section</td><td>4</td><td>200</td><td>22</td><td rowspan="2">4</td><td>1.35</td></tr>
<tr><td>QQE 03/12 (I) second section</td><td>4</td><td>200</td><td>21.5</td><td>1.25</td></tr>
</table>

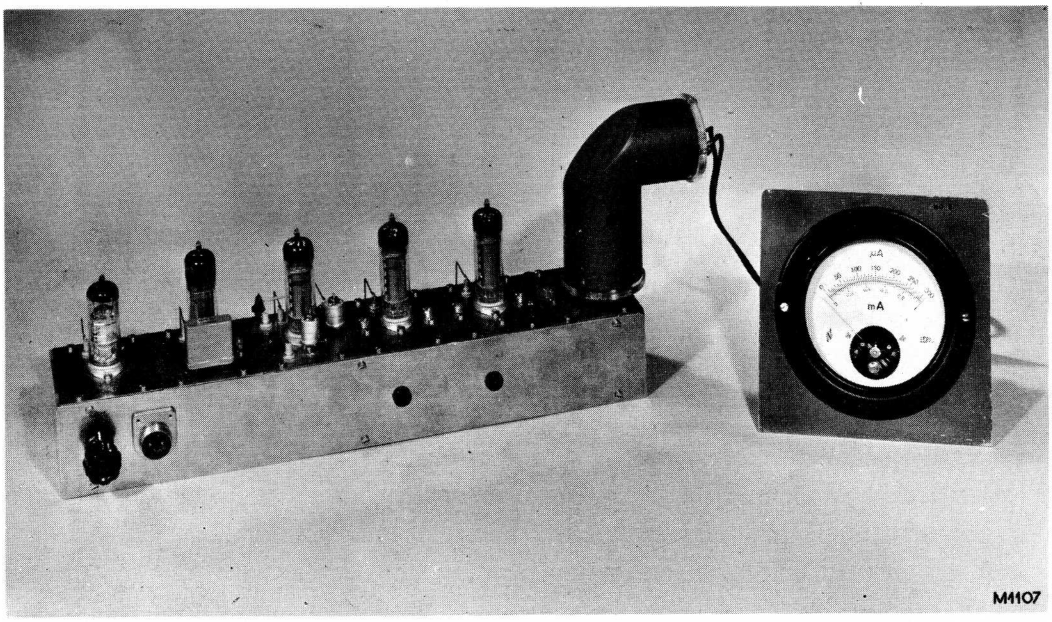


Fig.30. 200 Mc/s transmitter with modified modulator stage.

Under these conditions the negative grid bias of the first tube section is 102 V, and that of the second section 110 V. The screen-grid voltage is 92 V.

THE PUSH-PULL TRIPLER

The push-pull tripler is adjusted more economically than stated in the Technical Data under Operating Conditions. This is due to the fact that the tripler is used as a driver for the output stage, a comparatively low output thus being required. Both the common grid leak for the two sections and the screen-grid dropping resistor have a value of 68 kΩ. At the supply voltage of 200 V, the control grid current (I_{g1}) measured is 1.65 mA, hence the negative grid bias is 112 V. The screen-grid current (I_{g2}) is 1.1 mA and the screen-grid voltage is 125 V. Under these conditions the total anode current (I_a) for the two sections is 34 mA.

The anode coil in the last quadrupler stage has an inductance of 0.62 μH, and the anode circuit is tuned with a trimmer of 25 pF to the required frequency of 66.912 Mc/s. The input circuit of the push-pull tripler also has a tuning coil of 0.62 μH, but this is provided with a centre tap to which the common grid leak for the sections is connected. The grid circuit is tuned with a split stator trimmer of 6.4 pF the rotor of which is connected to chassis. The anode coil of the preceding stage is placed in the immediate vicinity of the grid coil (see figs 29 and 31).

The anode coil consists of a loop of 1.8 mm copper wire; the width of the loop is 18 mm, the length is 60 mm. This loop is provided with a centre tap for connection to the anode supply.

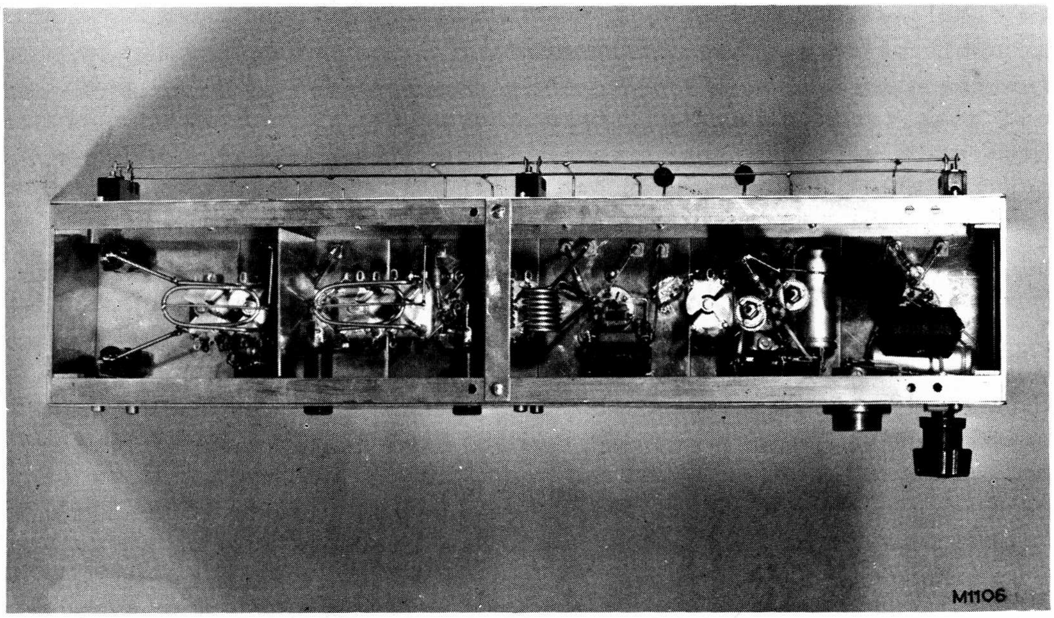


Fig.31. Modified 200 Mc/s transmitter seen from below.

THE PUSH-PULL OUTPUT STAGE

The output stage is equipped with another QQE 03/12, coupled to the tripler with a loop of 1.8 mm copper wire with a width of 18 mm and a length of 40 mm. This loop is also centre tapped for connection of the common grid leak (33 kΩ) of the two sections. The input circuit is tuned with a similar capacitor as that used in the output circuit of the tripler. Coupling between the two stages is obtained by mounting the two loops above each other and can be adjusted by slightly bending them.

The anode coil of the output stage consists of a loop of the same dimensions as that used in the tripler and is also provided with a centre tap for connection to the supply source.

Provision has been made for connecting the secondary of a modulator transformer in series with the anode supply. Considered from the point of view of modulation, the screen-grid dropping resistor is a voltage divider, but with respect to the direct current the two resistors are connected in parallel. Their values are 39 and 12 kΩ, which gives for the dropping resistor a value of 9.2 kΩ. With respect to the modulation the result is, however, that about 20% of the modulation is applied to the screen-grid. At this adjustment of the tube the total anode current (I_a) of the QQE 03/12 (III) is 67 mA and the screen-grid current (I_{g2}) is 2.6 mA, so that the screen-grid voltage is 176 V. The total grid current (I_{g1}) is 1.5 mA, which gives for the grid bias -50 V.

In the experimental set-up of the transmitter the output was measured with an incandescent lamp of 110 V, 25 W and a photocell. Such a circuit has the advantage that it can easily be calibrated with direct current. This output unit is connected to a loop of 1.8 mm copper wire; the width of the loop is 18 mm and the length is 50 mm. It is coupled to the anode circuit in a similar way as described for the coupling between the tripler and the output stage.

The output of the QQE 03/12 (III) is about 8 W, the output measured in the load is about 7 W. It has already been mentioned that this transmitter design has not been made for demonstrating the optimum results that can be obtained under the most favourable conditions and with the most refined components. It has, on the contrary, been made with average components and average tubes. Moreover, lower limit tubes have been tested in this circuit; with such a tube in the output stage the output power was about 85% of the average. In the other stages the use of lower limit tubes has no influence on the reliable operation and output.

POWER SUPPLY

From the data given in the preceding paragraphs the total H.T. supply can be determined. It totals to 200 V, 170.7 mA when the modulation system with Ferroxcube coil is used and to 200 V, 169.2 mA when the modulation system with a reactance tube is applied. The heater current is 3.06 A in the first case and 3.26 A in the latter, the voltage being 6.3 V. During stand-by the heater current can be reduced to 1.83 A and 2.03 A respectively when the current-saving circuit described on page 18 is used. When the heaters are fed from a 12.6 V supply source, the heater currents are 1.53 A and 1.72 A respectively (the E 80 F must then be fed over a series resistor of 31.5 Ω). A current saving circuit is then impracticable.

<table>
<tr><th>Tube</th><th>I_a
(mA)</th><th>I_{g2}
(mA)</th><th>I_{g1}
(mA)</th></tr>
<tr><td>Output tube
QQE 03/12 (III)</td><td>67</td><td>2.6</td><td>1.5</td></tr>
<tr><td>Tripler
QQE 03/12 (II)</td><td>34</td><td>1.1</td><td>1.65</td></tr>
<tr><td>Second quadrupler
QQE 03/12 (I)
second section</td><td>21.5</td><td rowspan="2">4</td><td>1.25</td></tr>
<tr><td>First quadrupler
QQE 03/12 (I)
first section</td><td>22</td><td>1.35</td></tr>
<tr><td>Oscillator E 80 CC
second section</td><td>11.5</td><td>-</td><td>1.95</td></tr>
<tr><td>F.M.modulator E 80 CC
first section</td><td>7</td><td>-</td><td></td></tr>
</table>

OVERLOADING OF TUBES BY ABSENCE OF GRID DRIVE

All the QQE 03/12 tubes employed in this transmitter are biased by the voltage drop produced by the grid current flowing through the grid leaks. This implies that when a tube is not driven, due to a failure or an incorrect adjustment in one of the preceding stages, it is operated without bias. This has no consequences for the tubes in the quadruplers and the tripler because the screen-grid dropping resistors are sufficiently high to prevent the anode current from attaining an inadmissible value. In the output stage, however, absence of grid bias would result in anode currents far in excess of the limiting value. It is for this reason that an additional screen-grid dropping resistor is incorporated in this stage.This resistor is connected in series with the other dropping resistors when the transmitter is adjusted, and short-circuited when the transmitter is ready to operate. This is obviously no protection against overlaoding of the output tube when, due to a failure in the pre-stages, the negative grid bias falls off. The use of an over-current relay that cuts out when the anode current increase above its limit, is therefore recommended to protect the output tubes.

A different solution consists in using either a cathode resistor in the output stage, or in applying fixed negative grid bias. As far as stationary transmitters are concerned this will not be objectionable, but in mobile equipment where utmost efficiency with respect to supply power is imperative, the higher H.T. supply voltage required cannot as a rule be accepted. When a mobile transmitter is fed from a 12 V storage battery the latter constitutes a handy supply source either for giving the cathode of the output tube a positive bias of 12 V or for giving its control grids a negative bias of the same value. If, in a mobile transmitter, the grid bias is obtained partially from the voltage drop in the grid leak and partially from a 12 V storage battery, there is no risk of the tube being overloaded when the driving power falls off due to a failure of one of the preceding stages, or when the grid bias drops to an excessively low value due to mismatching or incorrect tuning.

SPURIOUS SIGNALS

The spurious signal output of the transmitter described has been measured; the results of these measurements at a carrier frequency at 200.736 Mc/s are tabulated below.

Signal	Circuit fig.25		Modified modulator Circuit fig.28	
No.	Frequency (Mc/s)	Output (dB)	Frequency (Mc/s)	Output (dB)
1	133.824	-50	133.824	-54
2	192.372	<-64	192.372	<-64
3	196.554	-56	196.554	-64
4	204.918	-54	204.918	-64
5	209.100	-55	209.100	-64
6	401.472	-60	401.472	-55

The frequencies 2, 3, 4 and 5 are spurious signals, 6 is the second harmonic of the carrier, and 1 is the second harmonic of the driving signal of the tripler.

Considerable improvement can be obtained by replacing the single tuned circuit between the two quadruplers by a double tuned circuit. This improvement is approximately -10 dB.

Printed in Holland 20 D/5197